New Digital Voice Modes
Where are we now … ?
A 5-year overview.

COMMUNICATIONS ACADEMY
EMERGENCY COMMUNICATIONS
CONTINUING EDUCATION

P25 DIGITAL WIRELESS · SANS FIL NUMERIQUE · INALAMBRICO DIGITAL

DMR
DIGITAL MOBILE RADIO ASSOCIATION

Fusion

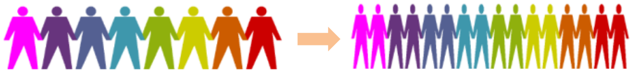
Andy Ruschak
KK7TR

Background

Lets go back 5 years

- Talked about digital voice as early as 2009 - 2010
- Promoted knowledge about digital voice modes used in Part 90 that could also be used in Part 97
  - APCO P25
  - ETSI DMR
  - NXDN
  - ICOM D-STAR (already existing at that time)
- Digital voice modes offer operational benefits to users:
  - Increased spectral efficiency due to narrow bandwidth
  - Increased voice call capacity due TDMA
  - High quality audio
  - Data-Centric capabilities

Better Spectral efficiency = More Users



25 kHz analog

12.5 kHz analog
12.5 kHz digital

Background

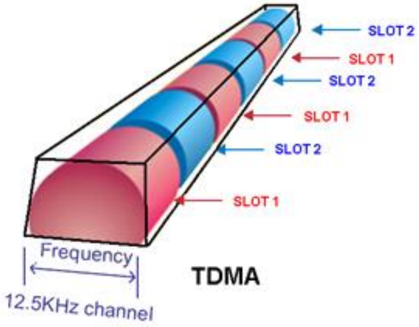
Some of the premises at the time (circa 2009-2010)

- Hams love to:
    - experiment
    - embrace new technology
    - be different
    - feel special and empowered
- One popular digital voice mode was primarily available (D-Star)
- Hams are cheap (OK, *frugal*)
- Surplus availability of digital commercial equipment would continue
- Large quantities of 1st Generation *used* P25 gear purchased under 9/11 era grants were hitting E-Bay

P25 Update

So, what's happened since then…?

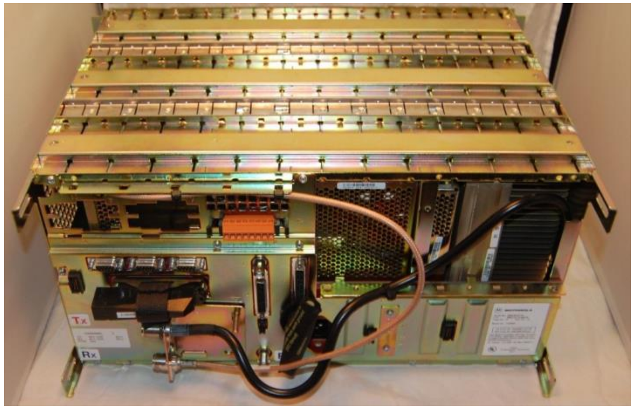
- APCO P25
    - - National standard for government land mobile radio systems
    - - Manufacturers offering 3rd generation radio and infrastructure
    - - Multi-band radios (V/U/700/800)
    - - P25 "Phase II" 2-slot TDMA now widely proliferated
    - - Prices are *slightly* decreasing due to competition and mass production
- P25 in amateur radio
    - - P25 has been implemented in a limited capacity in N. America
    - - The Seattle region has 6 x UHF and 1 x VHF P25 amateur repeaters
    - - Learning curve with the protocol, equipment and operational characteristics



P25 Lessons Learned

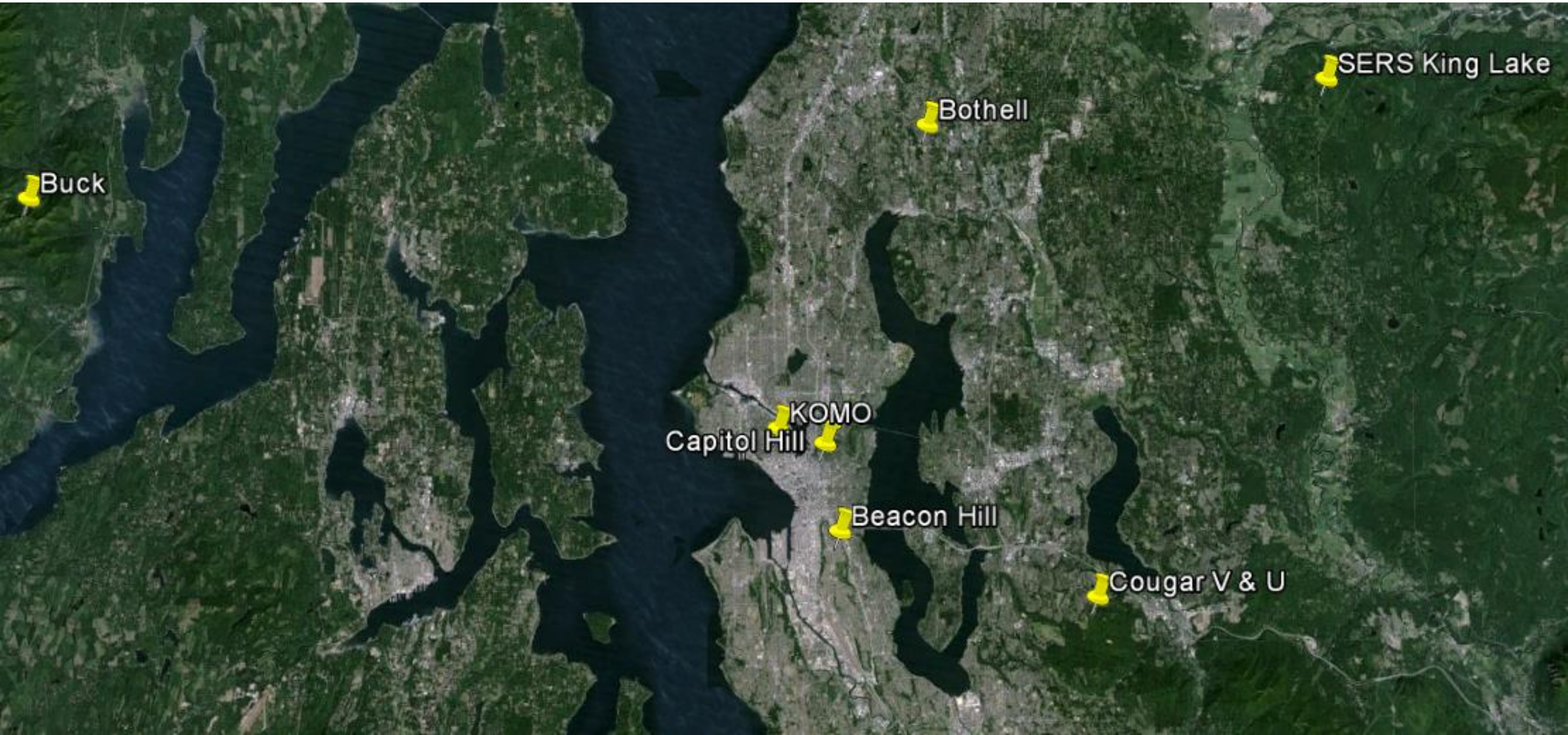
Some challenges with P25

- Build-out primarily based around one repeater platform
  - Motorola Quantar™
  - robust, but 1st generation design
  - used availability around $1000
  - requires specialized adapters and modem to link
  - based around older circuit switched technology (T1/DS0)



Regional P25

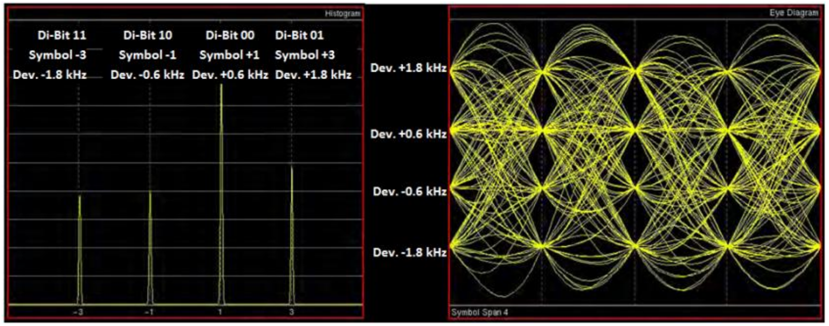
Current P25 Sites within Seattle Region

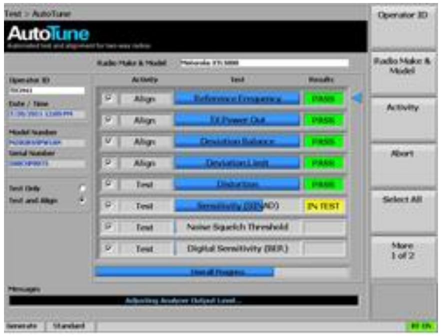


P25 Lessons Learned

Challenges with P25

- Lessons learned
  - relatively intolerant to multipath IX
  - radio requires very accurate alignment (deviation very critical for C4FM)
  - firmware revisions need to be harmonized
  - programmable settings need to be well understood
  - some board level component failures (>15-20 years operational life)





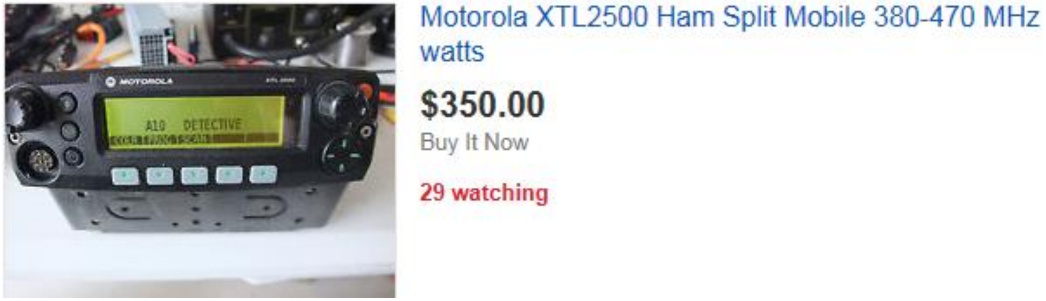
Activity	Test	Results
Align	Reference Frequency	PASS
Align	TX Power Out	PASS
Align	Deviation Balance	PASS
Align	Deviation Limit	PASS
Test	Distortion	PASS
Test	Sensitivity (SINAD)	IN TEST
Test	Noise Squelch Threshold	
Test	Digital Sensitivity (BER)	

Adjusting Analyzer Output Level...

P25 Lessons Learned

Challenges and Lessons Learned

- New equipment not realistically affordable
  - used equipment price similar higher-end amateur gear
  - ex. $250 - $500 portables, $300 - $800 mobiles on EBay
  - repeaters not easily networkable at a reasonable cost
  - radio should be checked and aligned before use
- “Not for Hams”..?
  - not exactly designed for amateur radio use (memory channel operation)
  - no VFO, front panel programming not standard
  - no embedded call sign field, must be derived from an ID alias list



Motorola XTL2500 Ham Split Mobile 380-470 MHz watts

$350.00

Buy It Now

29 watching

P25 Lessons Learned

But there is good…

- Audio Quality

  - superb “human-presence” sounding audio

  - superb quality radios, batteries

  - really neat accessories (ex. vehicular adaptor)

  - PTT ID is nice added feature

  - great support network of helping hams

- Mixed Mode and Narrowband (12.5 kHz) Operation

  - P25 and analog mode seamless

  - can still be used with IRLP and ARCOM controllers

- Monitoring of Public Safety

  - as some PS agencies transition to P25, make great “digital scanner” of conventional systems

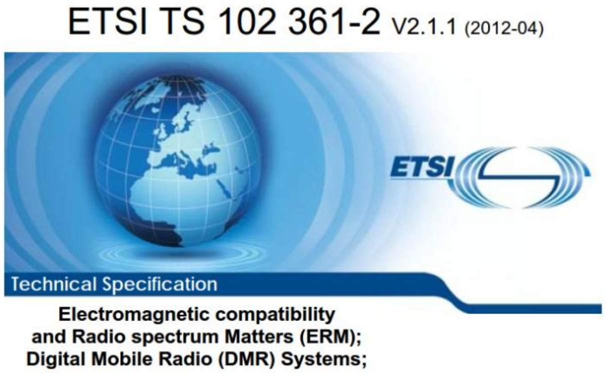
DMR Overview

DMR Background

- ETSI (European) standard for Digital Mobile Radio
  - Open Standard
  - Ratified in 2005
- Three (3) Tiers, I, II, III
  - Tier I Unlicensed
  - **Tier II Conventional, direct or repeater, non-trunked**
  - Tier III Trunked

European Telecommunications Standards Institute

For information, please go to: www.dmrassociation.org


ETSI TS 102 361-2 V2.1.1 (2012-04)

Technical Specification

Electromagnetic compatibility
and Radio spectrum Matters (ERM);
Digital Mobile Radio (DMR) Systems;

DMR Overview

DMR
DIGITAL MOBILE RADIO ASSOCIATION

ETSI

Background

- Not USA public safety grade, but utility grade solution
- Widespread acceptance internationally and in the USA
- Very large market presence by Motorola (MotoTRBO™)
- Very popular in Europe
- Radio and repeater pricing much closer to amateur product levels

  - subscriber units $350 - $800
  - Repeaters $1,500 - $2,000
- Recent market entry by Chinese manufacturers
  - sub $200 portable units available
- Adopted internationally for amateur radio use
- Analog & Digital Operation

HARRIS
sepura
Hytera
Respond & Achieve
simoco
Kirisun
tait
communications
MOTOROLA SOLUTIONS
Vertex Standard

DMR Overview

Call Types and Features

- Group Call
- Individual Call All Call (one way to *all* users of TS)
- Broadcast Call (one way to pre-defined users of TS)
- Priority and Emergency Call
- Polite/Impolite Channel Access (digital equiv. of BCLO/BTLO, etc.)
- IP over DMR
- Short Data Messaging (Status, SMS, defined)
- Radio Check
- GPS Location Reporting

DMR Overview

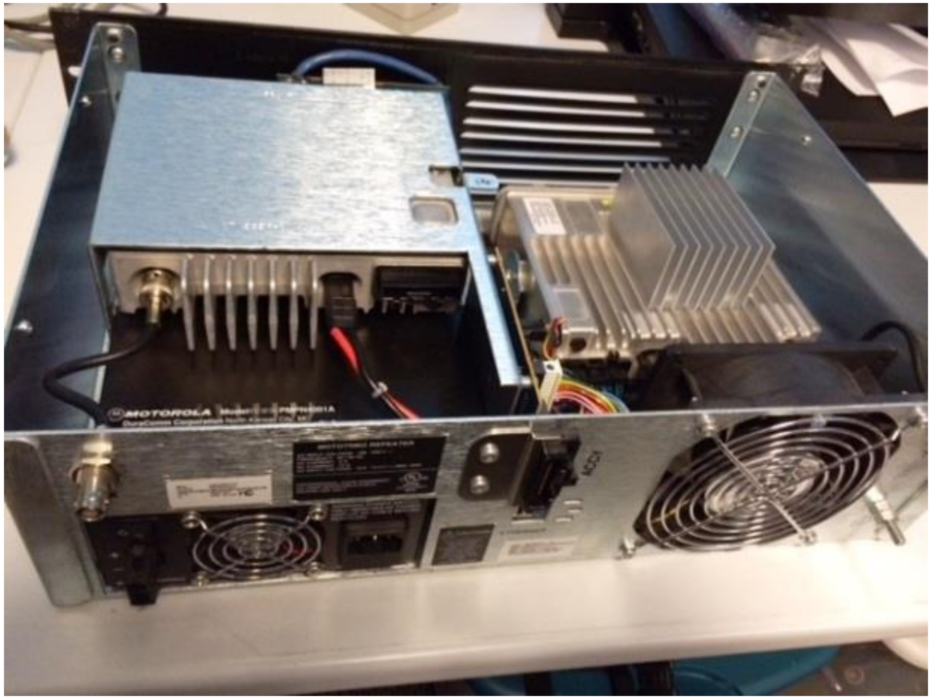
What does a DMR user radio look like?

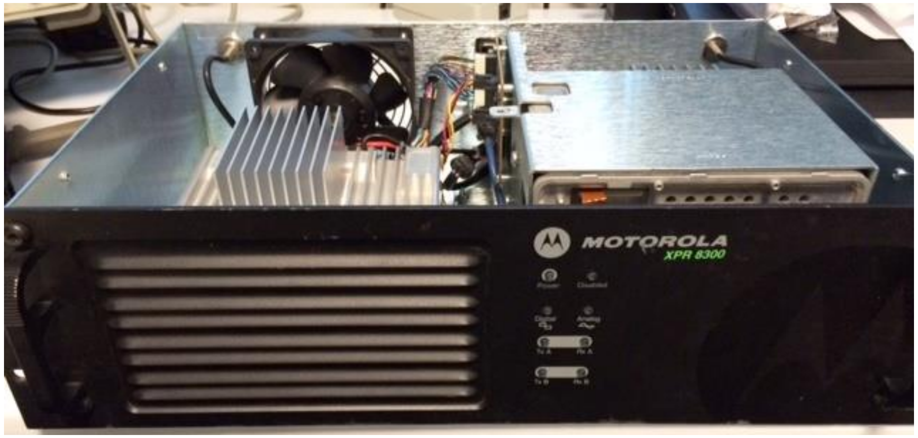
- Three Tiers, similar to P25 and professional grade radios
  - Tier I – no keypad or display (monochrome or color display)
  - Tier II – limited keypad, display
  - Tier III – full keypad, display
  - Cellular Style
- Part 90 Type Acceptance (Freq. Stability, Adj. Chan. Selectivity)
- VHF, UHF L, UHF H, 800 & 900

DMR Overview

What does a DMR repeater look like ?

- 1st & 2nd generation Motorola repeaters effectively 2x mobiles + control logic
- Low infrastructure cost
- 1 racked repeater, 2 voice channels

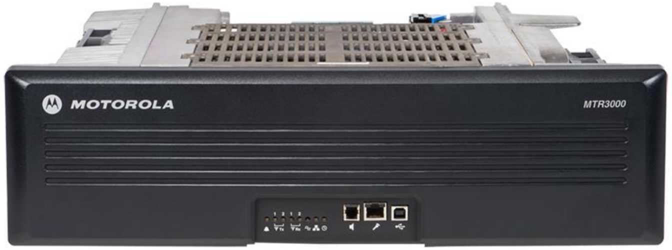


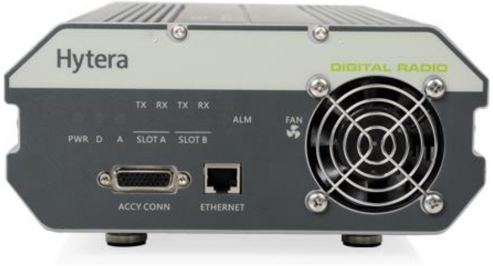


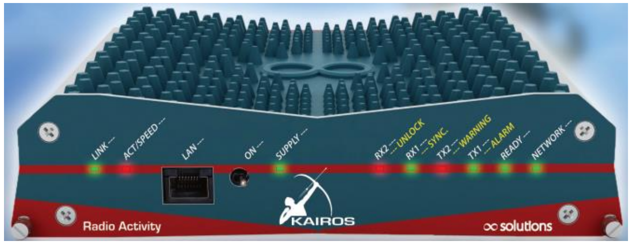
DMR Overview

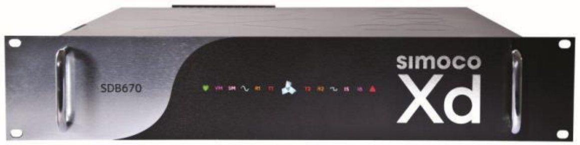
What does a DMR repeater look like ?

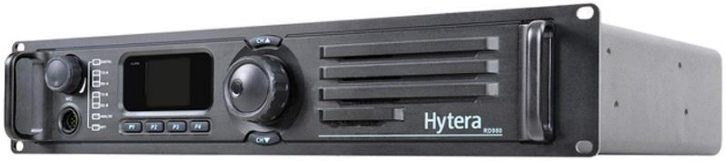
- Some other examples

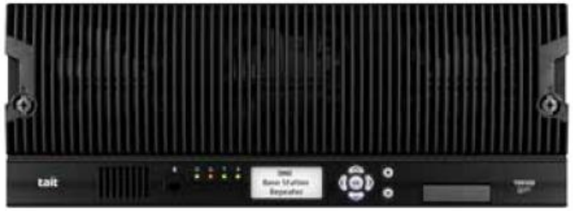


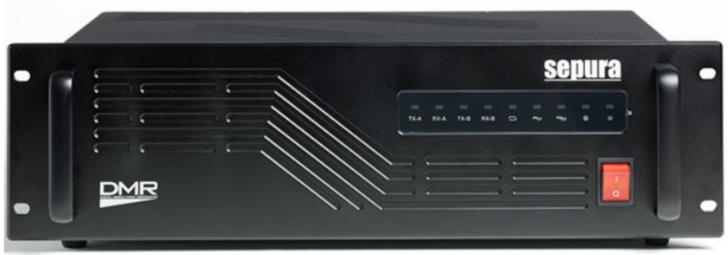








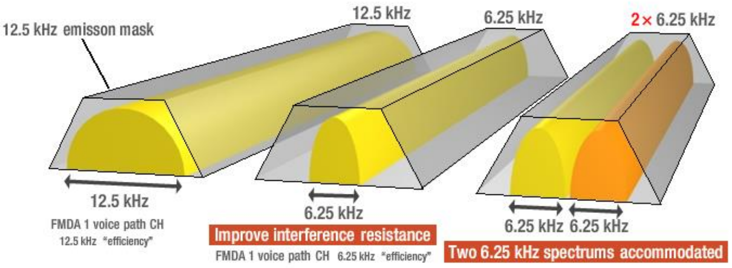


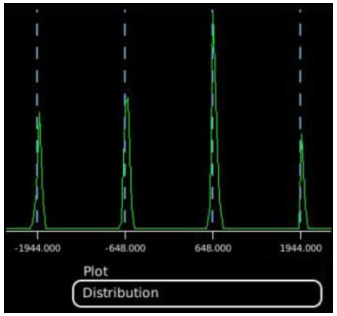


DMR Tech Overview

Technical Background

- 12.5 kHz BW (narrowband)
- C4FM ("4FSK") Modulation
  - same as P25, NXDN, and Yaesu Fusion
- State-of-the Art Forward Error Correction (FEC)
- DVSI AMBE++ VOCODER (adopted, not specified)
  - synthetic, modeled speech
  - very low bit rate 2450 bps voice + 1150 FEC = 3600 bps
  - very high voice quality, robust against strong background noise
  - proven technology MBE family adopted by TIA for APCO P25





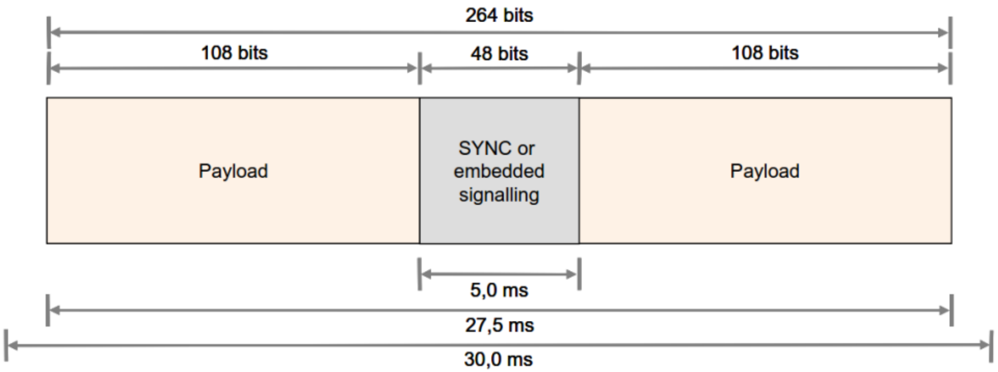
Information bits		Symbol	4FSK deviation
Bit 1	Bit 0		
0	1	+3	+1,944 kHz
0	0	+1	+0,648 kHz
1	0	-1	-0,648 kHz
1	1	-3	-1,944 kHz

Dibit symbol mapping to 4FSK deviation

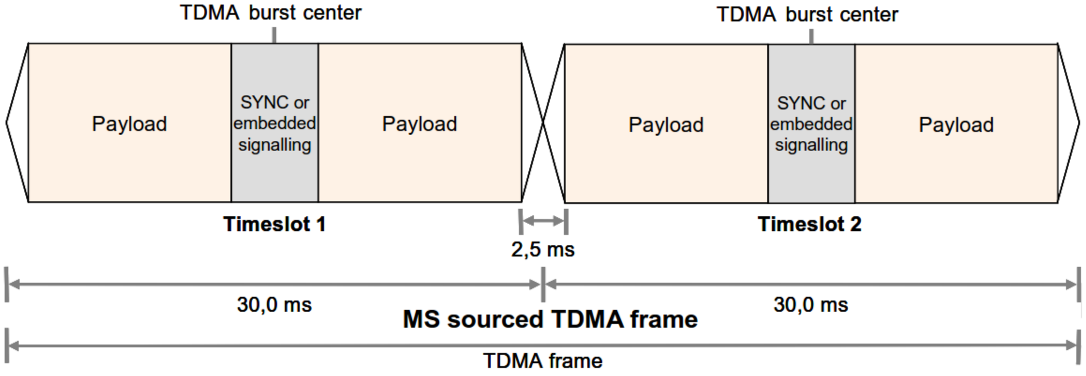
DMR Tech Overview

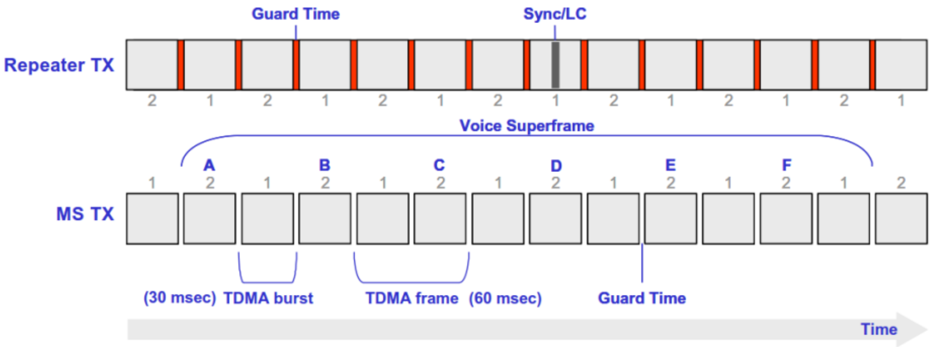
Technical Background

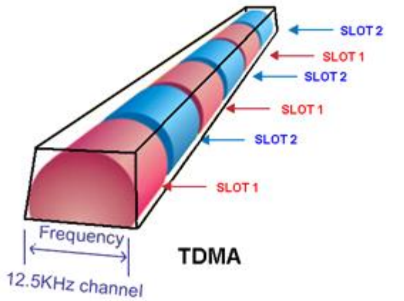
- 2-slot TDMA for 6.25 kHz equivalenc
- 30 ms slot, 50% duty cycle
- 216 bit payload (2x 108 bits)
- 2.5 ms guard time needed
    - - Tx ramp time
    - - propagation delay



Generic burst structure



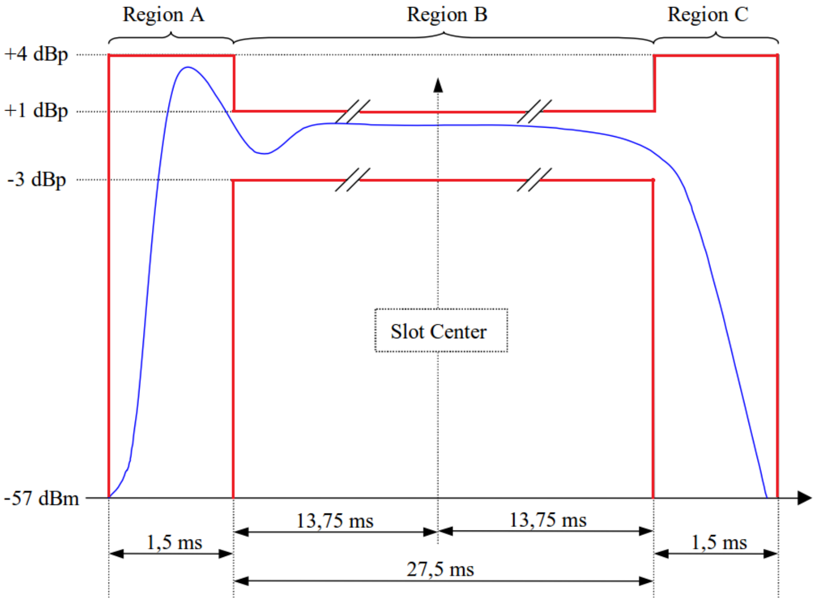




DMR Tech Overview

Radio Performance

- DMR Radios must have high performance characteristics in several areas:
  - transmitted power transients
  - power ramp time, time for carrier to "rise" and stabilize
  - clock stability and drift
  - frequency stability



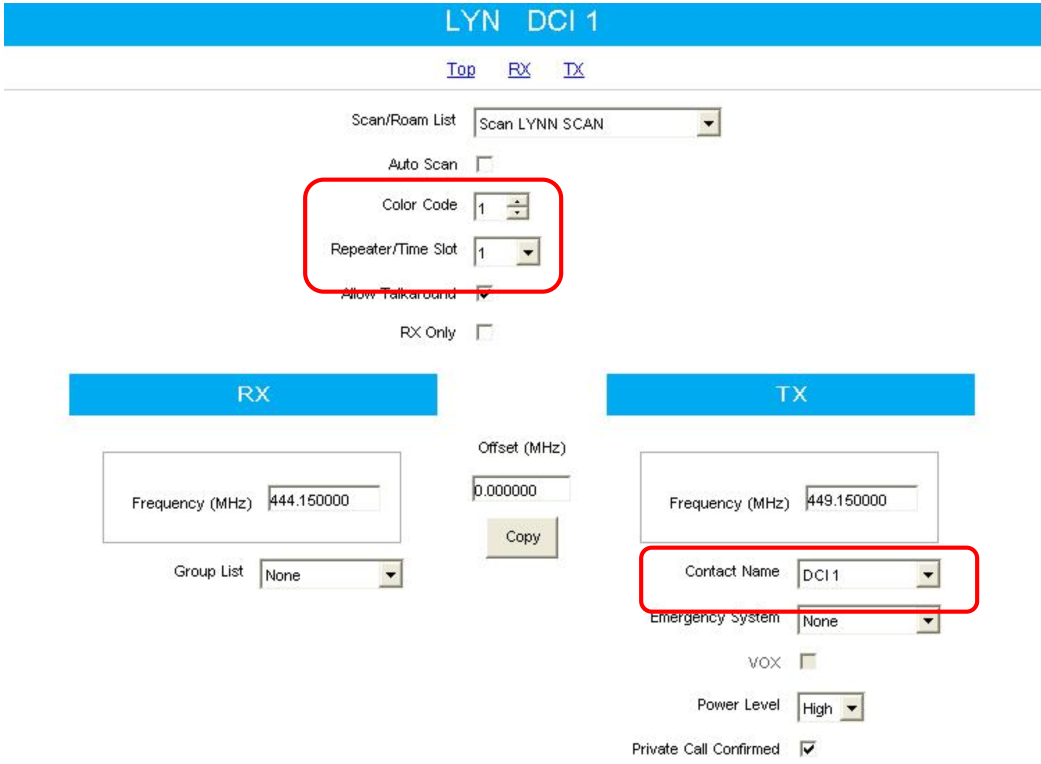
TDMA quirks

- Data (frame) sync is important
  - RPTR generates timing, mobiles sync to it
  - In simplex, source Tx becomes synch master
- Distance and propagation delay
  - 1 ms. "slop" built in compensates for disparate radio distances
  - different radios with different clock drifts
  - equates to approx. 45 mile range before 1 ms. "slop" is exceeded

DMR Basics

DMR Basics

- Radios programmed similar to analog
- Each radio has a unique ID that is registered before accessing the networks
- Info on repeater characteristics needed before a DMR call can be made – in either networked or stand-alone operation
  - Color Code
  - Time Slot assignment (1 or 2)
  - ID of called Group/Individual



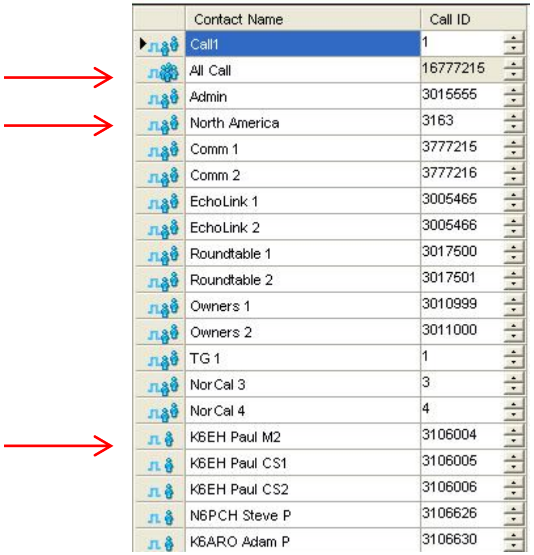
LYN DCI 1

Scan/Roam List: Scan LYNN SCAN
Auto Scan: ☐
Color Code: 1
Repeater/Time Slot: 1
Allow Talkaround: ☑
RX Only: ☐

RX
Frequency (MHz): 444.150000
Group List: None

Offset (MHz): 0.000000

TX
Frequency (MHz): 449.150000
Contact Name: DCI 1
Emergency System: None
VOX: ☐
Power Level: High
Private Call Confirmed: ☑

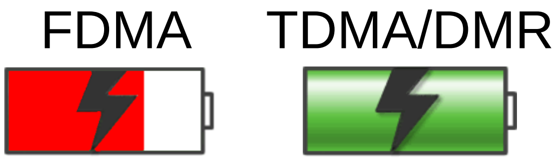


Contact Name	Call ID
Call1	1
All Call	16777215
Admin	3015555
North America	3163
Comm 1	3777215
Comm 2	3777216
EchoLink 1	3005465
EchoLink 2	3005466
Roundtable 1	3017500
Roundtable 2	3017501
Owners 1	3010999
Owners 2	3011000
TG 1	1
NorCal 3	3
NorCal 4	4
K6EH Paul M2	3106004
K6EH Paul CS1	3106005
K6EH Paul CS2	3106006
N6PCH Steve P	3106626
K6ARO Adam P	3106630

DMR Benefits

Digital vs. Analog

- Worldwide digital standard
- Over 6 major manufacturers of DMR radios
- Superior voice quality over older digital modes
- Longer battery life via TDMA 50% Tx / 50% Rx mode
- Supports multiple talk groups on one channel
- Supports data applications and simultaneous voice & data
- Commercial specs give rugged performance in urban RF environments



“TDMA radios indicate 19%~34% less required battery capacity than FDMA per hour, and “40% improvement in talk time over analog radios“ http://dmrassociation.org

DMR Feedback

Wealth of Information for Starters

- **MARC and DCI Websites loaded with info**
  - DMR technology
  - Network Topology
  - Operating protocol
  - How to get started
  - Even radio programming "bootstrap" starter files
- **Incredibly Professional and Knowledgeable People**
  - Many DMR users are "in the LMR industry"
  - Motorola employees (current & retired)
  - LMR shop technicians
  - Most embrace new technology
  - Some transitioning from or adding to D-Star operation

Websites:
www.dmr-marc.net
www.trbo.org

DMR Networking

Amateur DMR networking

- DMR intersite linking/networking protocol *not defined by ETSI*
- MotoTRBO™ has a a proprietary networking scheme IP SiteConnect™
- Limited to 15 sites and 100 users
- Beaconing cable for simple roaming

By the use of a special router, the original IP SiteConnect™ limitations are relieved.

- Distributed by Rayfield Communications
- “C-Bridge”

www.trbo.org

DMR-MARC
Motorola Amateur Radio Club Worldwide Network

DMR Networks

Two major wide area DMR based Amateur Networks

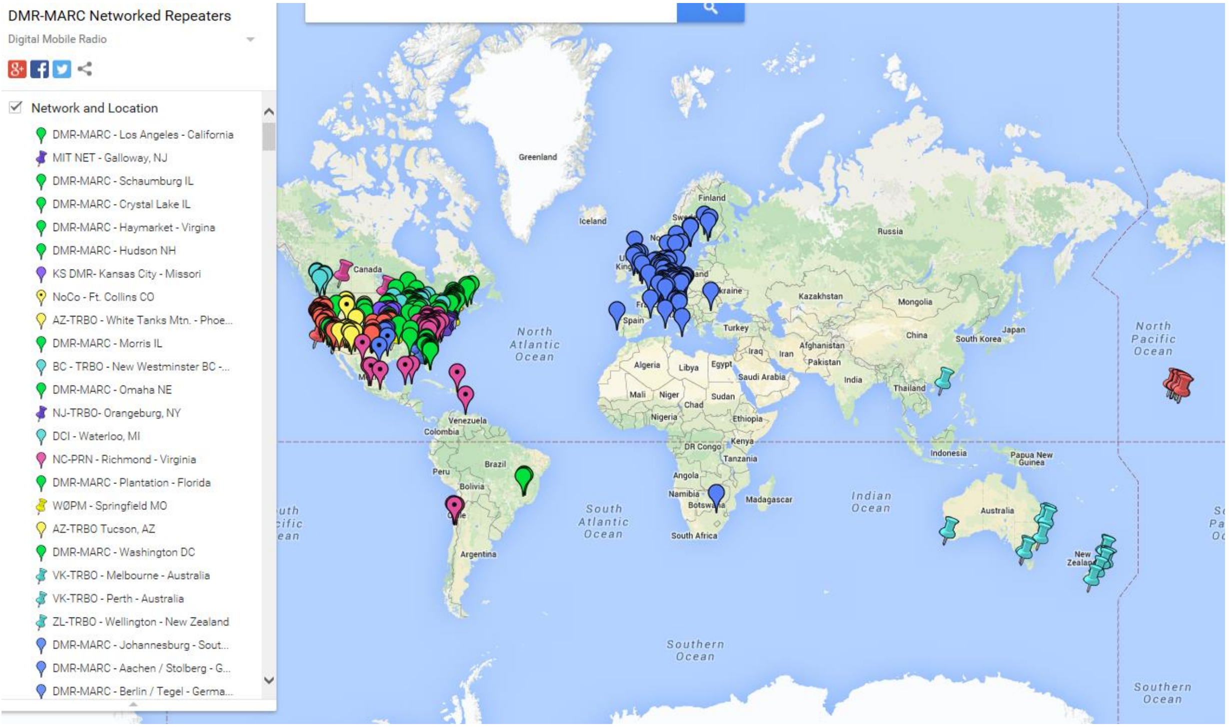
- DCI (has a bridge to MARC)
- MARC (has a bridge to DCI)

400 DMR repeaters in **37** countries
w/ >**11340** registered users

www.trbo.org

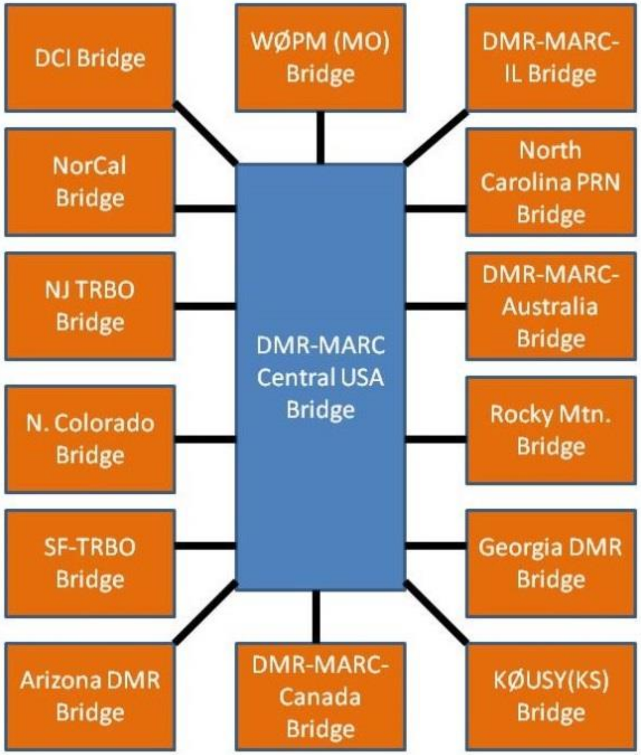
DMR-MARC
Motorola Amateur Radio Club Worldwide Network

Other international, regional or "private" networks



DMR-MARC Networked Repeaters
Digital Mobile Radio

☑ Network and Location
- DMR-MARC - Los Angeles - California
- MIT NET - Galloway, NJ
- DMR-MARC - Schaumburg IL
- DMR-MARC - Crystal Lake IL
- DMR-MARC - Haymarket - Virgina
- DMR-MARC - Hudson NH
- KS DMR- Kansas City - Missori
- NoCo - Ft. Collins CO
- AZ-TRBO - White Tanks Mtn. - Phoe...
- DMR-MARC - Morris IL
- BC - TRBO - New Westminster BC -...
- DMR-MARC - Omaha NE
- NJ-TRBO- Orangeburg, NY
- DCI - Waterloo, MI
- NC-PRN - Richmond - Virginia
- DMR-MARC - Plantation - Florida
- W0PM - Springfield MO
- AZ-TRBO Tucson, AZ
- DMR-MARC - Washington DC
- VK-TRBO - Melbourne - Australia
- VK-TRBO - Perth - Australia
- ZL-TRBO - Wellington - New Zealand
- DMR-MARC - Johannesburg - Sout...
- DMR-MARC - Aachen / Stolberg - G...
- DMR-MARC - Berlin / Tegel - Germa...



DCI Bridge

W0PM (MO) Bridge

DMR-MARC-IL Bridge

NorCal Bridge

North Carolina PRN Bridge

NJ TRBO Bridge

DMR-MARC-Australia Bridge

DMR-MARC Central USA Bridge

N. Colorado Bridge

Rocky Mtn. Bridge

SF-TRBO Bridge

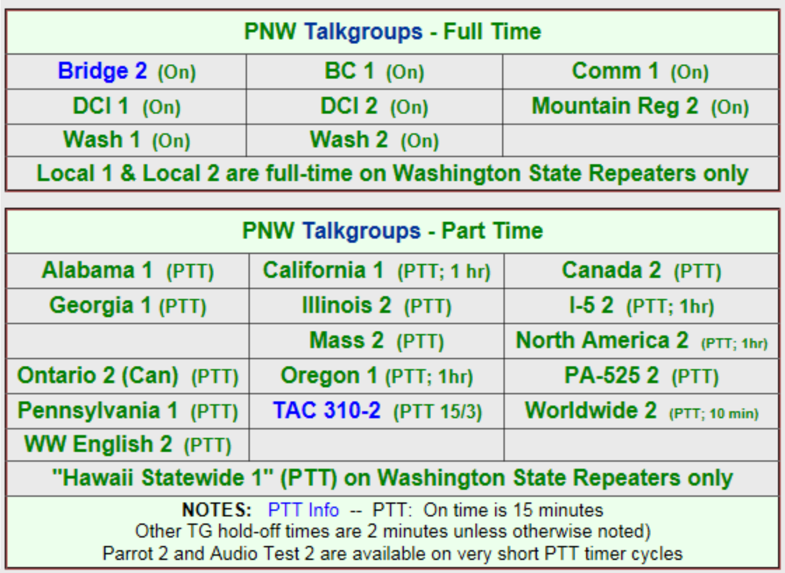
Georgia DMR Bridge

Arizona DMR Bridge

DMR-MARC-Canada Bridge

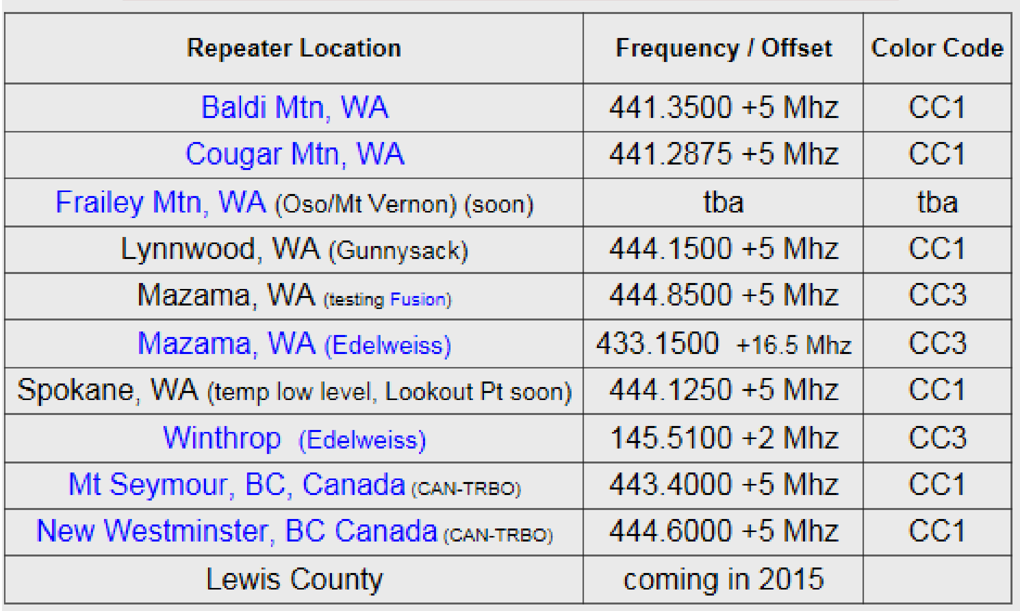
K0USY(KS) Bridge

Local DMR Repeaters

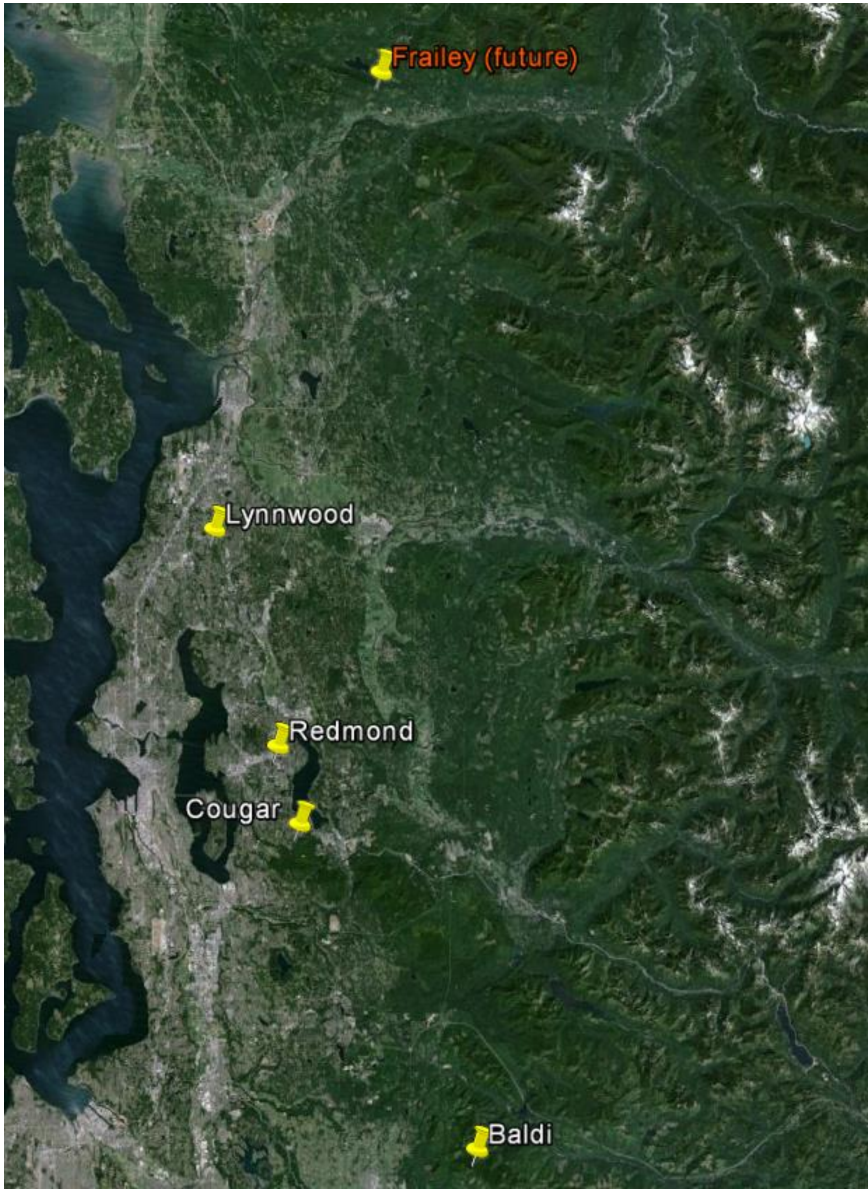


PNW Talkgroups - Full Time		
Bridge 2 (On)	BC 1 (On)	Comm 1 (On)
DCI 1 (On)	DCI 2 (On)	Mountain Reg 2 (On)
Wash 1 (On)	Wash 2 (On)	
Local 1 & Local 2 are full-time on Washington State Repeaters only		

PNW Talkgroups - Part Time		
Alabama 1 (PTT)	California 1 (PTT; 1 hr)	Canada 2 (PTT)
Georgia 1 (PTT)	Illinois 2 (PTT)	I-5 2 (PTT; 1hr)
	Mass 2 (PTT)	North America 2 (PTT; 1hr)
Ontario 2 (Can) (PTT)	Oregon 1 (PTT; 1hr)	PA-525 2 (PTT)
Pennsylvania 1 (PTT)	TAC 310-2 (PTT 15/3)	Worldwide 2 (PTT; 10 min)
WW English 2 (PTT)		
"Hawaii Statewide 1" (PTT) on Washington State Repeaters only		
NOTES: PTT Info -- PTT: On time is 15 minutes Other TG hold-off times are 2 minutes unless otherwise noted) Parrot 2 and Audio Test 2 are available on very short PTT timer cycles		



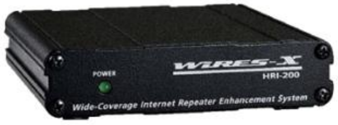
Repeater Location	Frequency / Offset	Color Code
Baldi Mtn, WA	441.3500 +5 Mhz	CC1
Cougar Mtn, WA	441.2875 +5 Mhz	CC1
Frailey Mtn, WA (Oso/Mt Vernon) (soon)	tba	tba
Lynnwood, WA (Gunnysack)	444.1500 +5 Mhz	CC1
Mazama, WA (testing Fusion)	444.8500 +5 Mhz	CC3
Mazama, WA (Edelweiss)	433.1500 +16.5 Mhz	CC3
Spokane, WA (temp low level, Lookout Pt soon)	444.1250 +5 Mhz	CC1
Winthrop (Edelweiss)	145.5100 +2 Mhz	CC3
Mt Seymour, BC, Canada (CAN-TRBO)	443.4000 +5 Mhz	CC1
New Westminster, BC Canada (CAN-TRBO)	444.6000 +5 Mhz	CC1
Lewis County	coming in 2015	



FUSION Overview

Background

- Yaesu Amateur Radio Digital Standard
  - Open Standard ?
  - Released in 2013
  - Full product family
- C4FM
  - 12.5 kHz NB (only 25 kHz BW on analog side)
  - 9600 bps
  - FMDA
  - AMBE VOCODER



FUSION Overview

Channel Modes

V/D Mode Type 1	Simultaneous Voice / Data communication
V/D Mode Type 2	Simultaneous Voice / Data communication
Full Rate Data Mode	High-speed Data transmission mode
Full Rate Voice Mode	High-quality Voice mode
Analog FM	Standard analog mode

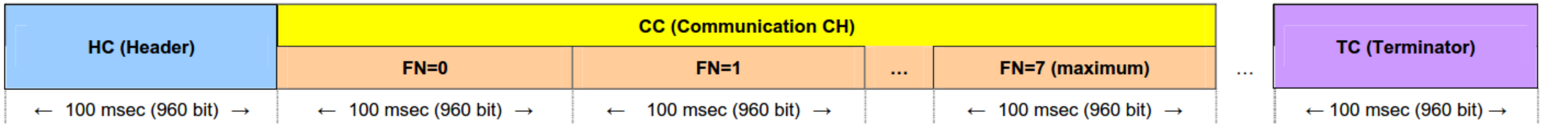
Initial reports and feedback are that digital audio quality is excellent

Leverages AMBE 2+ VOCODER operate in full rate (7200 bps) or half-rate (3600 bps) mode.

Choose what balance of voice quality vs. data transmission rate you desire

100 msec. frame length – similar to P25 (uses 88 msec. voice frame length)

Frame Composition

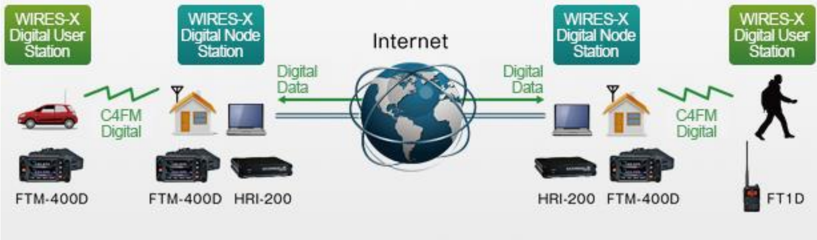


HC (Header)	CC (Communication CH)				…	TC (Terminator)
	FN=0	FN=1	…	FN=7 (maximum)		
← 100 msec (960 bit) →	← 100 msec (960 bit) →	← 100 msec (960 bit) →		← 100 msec (960 bit) →		← 100 msec (960 bit) →

FUSION Overview

Networking

- Current iteration not elegant
    - Mobile control station & Wires-X box
    - Windows PC
    - Nodes and chatrooms
- Node station connects to the Internet
    - used as an access point
    - connects to nodes and “rooms”
- Server located in Japan
    - Lose it, you lose the network
    - Many nodes only operational in analog
- Future iterations promise direct repeater IP interface


WIRES-X Digital User Station
WIRES-X Digital Node Station
Internet
WIRES-X Digital Node Station
WIRES-X Digital User Station
C4FM Digital
Digital Data
Digital Data
C4FM Digital
FTM-400D
FTM-400D
HRI-200
HRI-200
FTM-400D
FT1D

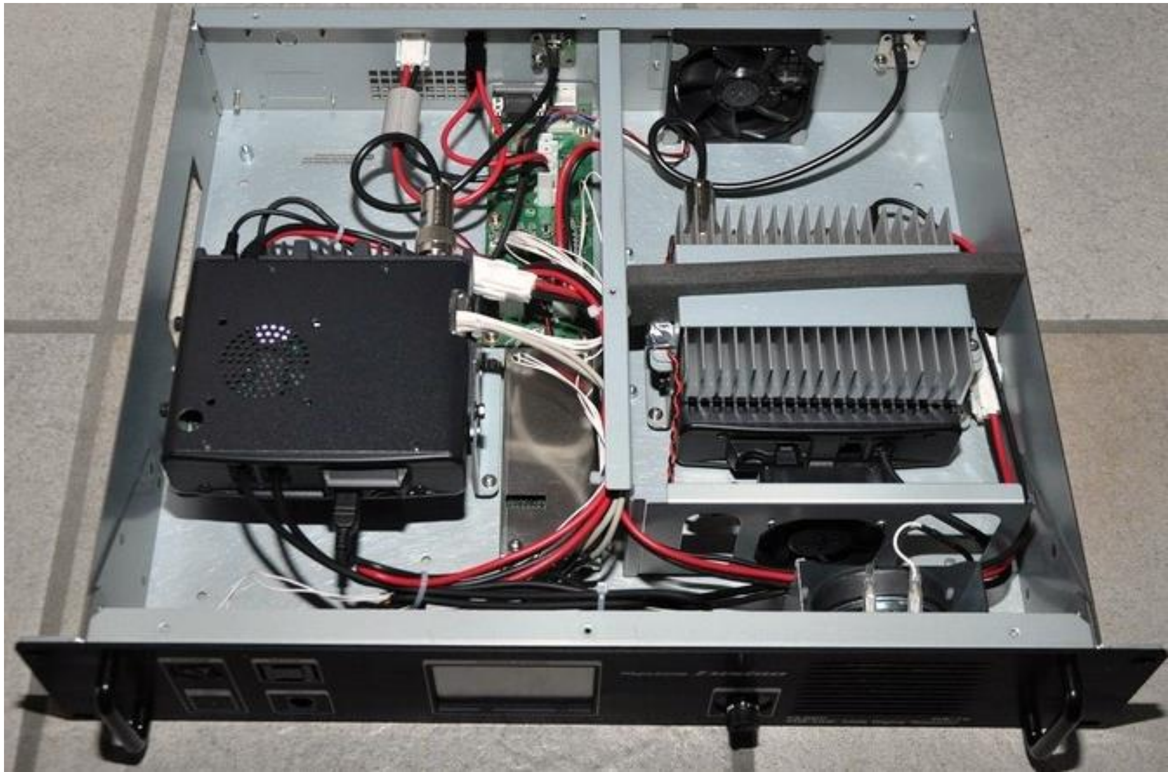
FUSION Overview

What does a FUSION repeater look like ?

- Yaesu FUSION repeater effectively 2x mobiles + control logic
- Supports dual-band, cross-band and mixed mode (analog & C4FM) operation
- Networkable via WIRES-X system

Concerns

- PA Duty Cycle/Lifespan
- Receiver selectivity (WB Rx)
- No support for 12.5 kHz analog
- Coordination must be for standard channel spacing



Personal Observations*

State of the Professional industry in Digital Voice Radio Technology

- The Industry has spoken:
  - C4FM is the de facto modulation format for low data rate digital voice
  - DVSI VOCODER technology is most advanced for low-rate data
  - TDMA appears to have initial market dominance over 6.25 kHz FDMA
  - Communications interoperability the prime consideration
  - analog FM will increasingly become a “fallback” mode in the future
- Reliable, high-speed data was never a consideration @ 12.5/6.25 kHz
- LTE and Voice-over-LTE looms as the potential long-term successor to all (voice & data)
  - Mission critical voice for LTE standard is part of Release 13 (3Q 2016)

Personal Observations*

A Worrying Trend in Amateur Digital Voice

- Only “pseudo-proprietary”/”pseudo-open” technology appears to be mass-produced and marketed to the amateur radio
  - D-Star™: open, legacy offering, *effectively* one major vendor
  - Fusion™: open, new, currently *one* vendor
  - DMR: open, emerging, multiple vendors, limited amateur marketing
  - P25: open, mature, *expensive*, no vendors marketing to amateurs
- No interoperability or compatibility between protocols
  - physical layer / air interface incompatibility
  - network layer incompatibility
  - we’re still at the analog FM level for interoperability
- This same paradigm that led to the creation of APCO P25 standard and ISSI
- What price do we pay in interoperability for choices…?

How many radios do you want to own to enjoy digital voice?

How do you leverage benefits/capabilities of digital in EMCOM with disparity?

Do you care …?

Personal Observations*

Technology Convergence

- Ideally the market and best technology drives R&D and manufacture
- Market feedback and user requirements drive development
- Needs of the many outweigh the needs of the one, or few
- Interoperability intrinsic /inherent in the end goal

Technology Divergence

- Choices, and more choices
- Proprietary standards (real or pseudo) fragments/partitions the market
- This is a business, right ? Protect your investment.
- Interoperability becomes a complex problem or else a compromise
    - analog gateway (well, golly, why have digital technology anyway?)
    - SIP Session Initiation Protocol, the near-term savior?
    - human aspect, identifying with one group or technology following

Personal Observations*

How did this happen and should we be concerned…?

- New product development and market input… where does it really come from?
  - amateur radio limited market compared to Part 90
  - public service / emergency comms in Part 97 not universal
- If trends in the professional sector (and years of evaluating interoperable communications) are any indication, we are heading in the wrong direction regarding digital voice modes
- More partitioning of the market
  - creation of "technology enclaves"
  - pick one (you may only be able to afford one)
  - why does embracing a technology mean marriage to a company?
- "Andy, just chill, this is not public safety, its ham radio!"
- Just one common digital voice mode… what are you anyway, a socialist?

Are we asleep at the wheel…? How seriously do we take our hobby…?

Final Thoughts

What do I take away from this…?

- Similar issues facing amateur radio have been addressed by the public safety and professional radio industry over a decade ago
  - voice w/advanced features (audio quality, PTT ID, EMER)
  - low rate data (position, messaging)
  - broadband / high rate data (link connectivity, file transfer)
  - NB, TDMA (spectrum conservation)
- Open standards and protocol development is the future
- User requirements, specifications, technology choices and capabilities are now being formed by closely coordinated working groups, technical committees representing the interests of end users, *not radio manufacturers*

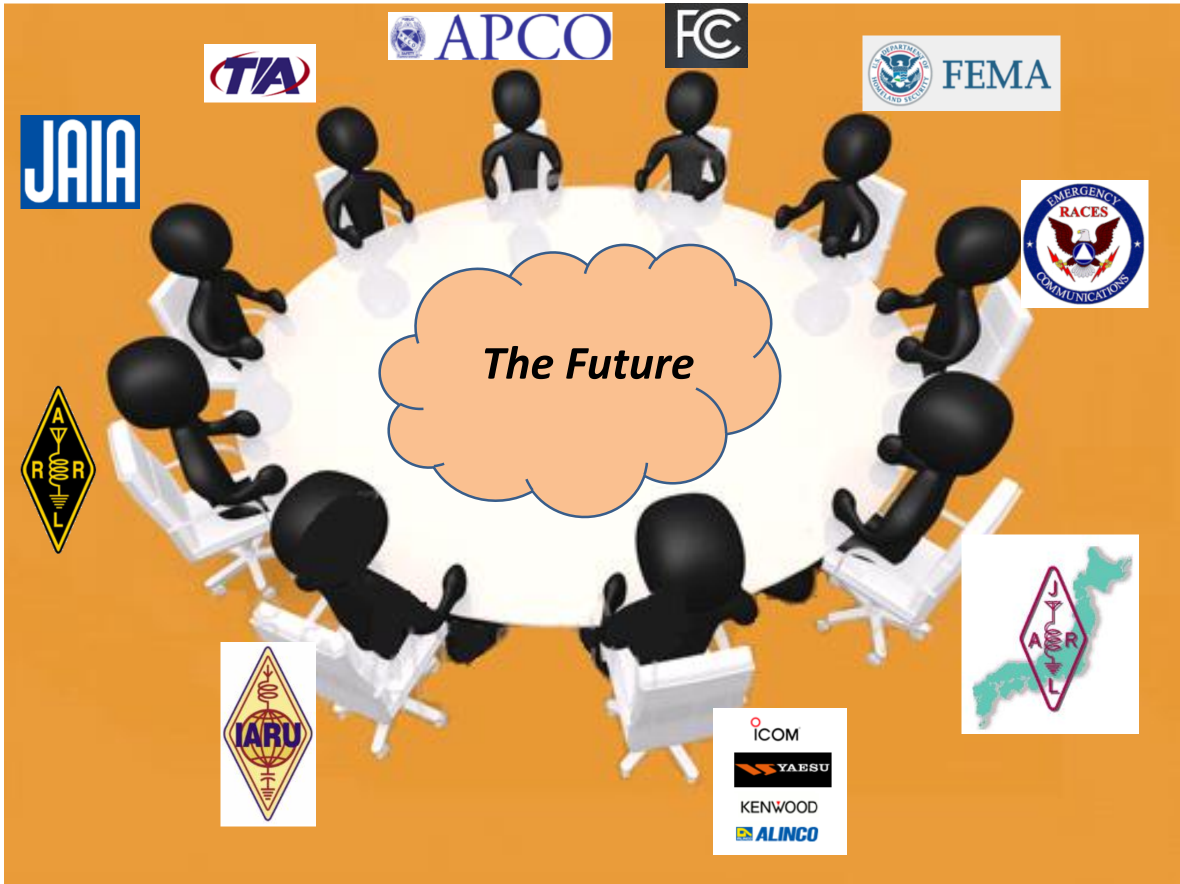
Final Thoughts

As a radio service, user group, and business market, where do we stand..?

- Should the ARRL more actively represent the future direction of amateur technology development ? If not, then who…?
- Should the amateur community organize through committee or representation to:
    - define future communications technology
    - define features and capabilities to support EMCOM
    - create standards documents to immortalize decisions and direction ?
- Would the industry:
    - listen ?
    - cooperate ?
    - respond with product technology that still allow fair market competition?
- Maybe the Chinese Radio Manufacturers will listen…. they are flooding the market with incredible technology and incredible product flexibility….

IMAGINE IF YOU WILL…

- Designating stakeholders in the future of amateur radio technology
- Forming committees, sharing expertise, discussing both problems and solutions
- Directly engaging the industry, the government, and manufacturers on next generation amateur products
- Industry producing digital radio products that hit the target much better for the masses



THANK YOU !

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